

UNITED STATES PATENT APPLICATION
FOR
ELECTRONIC INTERFACE FOR LONG REACH OPTICAL TRANSCEIVER
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BACKGROUND

Field of the Invention

[001] The present invention relates to optical communication systems and, particularly to an electronic interface for small form factor high-speed optical transceivers with high sensitivity optical receivers.

Discussion of related art

[002] There is currently a demand for high-speed, long-distance, cost-effective, and highly integrated optical transceiver systems. Therefore, optical receiver systems that are high performance, low cost, and are of small size are desired. A transceiver typically includes both a transmitter system and a receiver system. A fiber optical transceiver, therefore, can include a receiver optical sub assembly (ROSA), a transmitter optical sub assembly (TOSA), and an electronic interface connecting the ROSA and TOSA.

[003] For short reach and medium distance transmission, the ROSA may include a PIN photo detector based receiver for detecting light from an optical fiber. For long reach transceivers (e.g., for transmission over tens of kilometers), however, high sensitivity receivers are required to compensate for the optical signal loss due to long optical fibers. In long distance systems, then, an avalanche photodiode (APD) can be utilized instead of a PIN photodiode because of its higher sensitivity and lower noise characteristics.

[004] The TOSA can include a laser diode and optics for coupling optical signals generated by the laser diode into a fiber. The electronic interface to the TOSA and ROSA, then, includes drivers for the TOSA, receivers for the ROSA, and power

supplies to power the laser diodes and the receiver chips of the ROSA and TOSA. In conventional systems, the electronic circuitry of the power supplies, the transmission circuitry, and the receiver circuitry are well separated in order to minimize the amount of noise generated on the received signals and on the transmitted signals due to the electronics. However, such an arrangement can require a great deal of space for the transceiver system.

[005] Therefore, there is a need for optical transceiver systems, and in particular for long reach optical transceiver systems that have a small form factor and that are arranged to minimize interference and noise on the received signals.

SUMMARY

[006] In accordance with embodiments of the present invention, a transceiver system is presented that has a small form factor. A transceiver system according to the present invention includes a receiver optical sub assembly, a transmitter optical sub assembly, and an electronic interface coupled to the receiver optical sub assembly and the transmitter optical sub assembly, wherein the electronic interface utilizes a split ground arrangement in a multi-layer circuit board assembly. The result of the split ground, multi-layer circuit board arrangement is that a high-voltage bias supply required for high-speed transceiver functions can be isolated from the transceiver. Further, in some embodiments, internal conducting layers can operate as shields to further assist in isolating the receiver functions from the high-voltage signal generation.

[007] These and other embodiments are further discussed below with reference to the following figures.

BRIEF DESCRIPTION OF THE FIGURES

[008] **Figure 1** shows a transceiver according to certain embodiments of the present invention.

[009] **Figure 2** shows a block diagram of an electronic interface according to some embodiments of the present invention.

[010] **Figure 3** illustrates a multi-layer board according to some embodiments of the present invention.

[011] **Figure 4** shows a circuit diagram of an embodiment of electronic interface according to some embodiments of the present invention.

[012] **Figures 5A and 5B** show a first layer of a multi-layer circuit board according to the present invention.

[013] **Figure 6** shows a second layer of a multi-layer circuit board according to some embodiments of the present invention.

[014] **Figure 7** shows a third layer of a multi-layer circuit board according to some embodiments of the present invention.

[015] **Figure 8** shows a fourth layer of a multi-layer circuit board according to some embodiments of the present invention.

[016] **Figure 9** shows a fifth layer of a multi-layer circuit board according to some embodiments of the present invention.

[017] **Figure 10** shows a bottom layer of a multi-layer circuit board according to some embodiments of the present invention.

[018] **Figure 11** shows a cross section of an embodiment of multi-layer circuit board according to some embodiments of the present invention.

[019] In the figures, elements having the same designation have the same or similar function.

DETAILED DESCRIPTION

[020] **Figure 1** illustrates a transceiver 100 according to some embodiments of the present invention. In some embodiments, transceiver 100 is housed in a metallic case (not shown). Transceiver 100 includes a receiver optical sub assembly (ROSA) 110, a transceiver optical sub assembly (TOSA) 120, and a multi-layer board 130. ROSA 110 includes optics for receiving optical signals from an optical fiber and focusing the optical signals onto a detector. The detector of ROSA 110 converts the optical signals into electrical signals that are coupled to the electronic interface formed on multi-layer board 130. Typically, electrical connections between ROSA 110 and the electronic interface circuit formed on multi-level board 130 include conductors for carrying a high-voltage bias voltage, a power supply voltage, a differential current signal, and a ground. The electrical signals and their characteristics depend on the particular optical detector and supporting circuitry housed in ROSA 110. For example, if ROSA 110 includes an avalanche photodiode and supporting transimpedance amplifier for utilization in a long-reach optical system, then the bias voltage may be about 70 V while the power supply voltage is about 3.3 V. The differential voltage (i.e., the voltage across the conductors carrying the differential current signal) can be as high as 400 mV, depending on the intensity of the optical radiation incident on the active area of the photodetector.

[021] TOSA 120 converts electrical signals into optical signals for transmission on an optical fiber. As such, TOSA 120 typically includes a laser diode and optics for coupling the light generated by the laser diode into an optical fiber and a photo diode to monitor the average optical power. Electrical signals into TOSA 120, then, can include power and ground for the laser diode as well as electrical signals to be transmitted optically over an optical fiber.

[022] An electronic interface circuit according to the present invention can be built on multi-level board 130. Multi-level board 130, then, includes electrical connections to ROSA 110 and to TOSA 120. Additionally, multi-level board 130 includes an electrical connection 131 for making electrical connections external to transceiver 100. Electrical connection 131 can be any electrical connector, for example a PCB edge finger connector. Further, transceiver 100 may include covers 132 and 133 for protecting and shielding the electrical connections between ROSA 110 and the electronic interface on multi-layer board 130 and TOSA 120 and the electronic interface on multi-level board 130. An embodiment of ROSA 110 that can be utilized in transceiver system 100 is disclosed in U.S. Application Serial No. {**Attorney Docket No. 09136.0005**}, which is filed concurrently with the present disclosure, and is herein incorporated by reference in its entirety.

[023] **Figure 2** shows a simplified block diagram of an example of electronic interface 200 that can be formed on multi-layer board 130. Electronic interface 200 includes electrical connection 131 where signals can be coupled to the remainder of electronic interface 200. Electronic interface 200 includes a transmitter portion 240 coupled to board traces 220. Transmitter portion 240 receives signals from connector 131 and provides signals to TOSA 120 through board traces 220. Transmitter portion 240, for example, can include a laser driver to control a laser diode in TOSA 120. Receiver portion 230 receives signals from board traces 210, which is coupled to ROSA 110, and provides signals to connector 131 in response to the received signals from connector 210. The signals from ROSA 110 are derived from an optical detector which, in some embodiments, can be an avalanche photodiode.

[024] The photodetector of ROSA 110, in some embodiments, can require application of a large bias voltage. An avalanche photodiode, for example, can require a

bias voltage of about 70V or more. Therefore, electronic interface 200 includes a high-voltage power supply 260 that generates the bias voltage for the photodetector of ROSA 110. In some embodiments, high-voltage power supply 260 can be a DC-DC switching voltage supply. In high-voltage power supply 260, a low-voltage input signal (e.g., a 3.3V power supply input) can be converted to a high voltage output signal (e.g., about 70V) in the switching power supply of high-voltage power supply 260.

[025] In some embodiments of electronic interface 200, a microcontroller system 250 can monitor and control operation of electronic interface 200. Microcontroller system 250 can monitor transmitter 240, receiver 260, and high-voltage power supply 260 and provide status signals to connector 131. Further, microcontroller system 250 may receive signals through connector 131 that relate to control of transmitter 240, receiver 230, and high-voltage power supply 260.

[026] High-voltage power supply 260, however, can provide a large source of interference to signals in both transmitter portion 240 and receiver portion 230. Therefore, in a transceiver system according to some embodiments of the present invention, transmitter portion 240 and receiver portion 230 are shielded from high-voltage power supply 260.

[027] **Figure 3** shows an embodiment of multi-level board 130 that illustrates the configuration of electronic interface 200. In the embodiment of multi-level board 130 shown in **Figure 3**, six layers of board are formed and coupled together. High-voltage power supply 260 is formed on layer 301, the top layer, of multi-level board 130. Transmitter 230 and receiver 240 are formed on layer 306, the bottom layer, which is on the opposite side of multi-layer board 130. Additionally, as shown in **Figure 2**, the ground of receiver 230 and on connector 210 is split from the ground of transmitter 240 in order to help isolate receiver 230 from the remainder of electronic interface 200. The

grounds of high-voltage power supply 260 and microcomputer system 250 can be the same as the ground of transmitter 240. Although a six-layer stacking embodiment is illustrated in this disclosure, other layer arrangements can be utilized. In accordance with some embodiments of the present invention, a transceiver system includes an electronic interface arranged on a multi-level board where high-voltage power supply 260 is electrically isolated from transmitter 240 and receiver 230.

[028] Therefore, in the embodiment illustrated in **Figure 3**, layer 301 will include metallic traces for the circuitry of high-voltage power supply 260. Layer 301 may also include metallic traces for portions of connector 131 and connectors 220 and 210. Layer 302 includes metallic vias to provide electrical connection from underlying boards to portions of connector 131 and connectors 220 and 210 (not shown). Layer 303 includes vias for electrical connections between boards and a copper isolation plane 307, which may occupy some or all of layer 303. Layer 304 includes metallic traces to provide interconnects between circuit elements. Electrical connections can be made through vias in other board layers. Layer 305 provides electrical vias between layer 304 and layer 306. Layer 306 provides metallic traces for the circuitry of, for example, receiver 230 and transmitter 240.

[029] Board layers 301, 302, 303, 304, 305, and 306 are positioned in contact with one another and connections between boards can be made in well-known ways, for example by pressure, adhesives, and heating the assembly, to form multi-level board 130. The components of electrical interface 260 can then be positioned on layers 301 and 306 and electrically coupled to multi-level board 130.

[030] In some embodiments of multi-level board 130 according to the present invention, copper isolation plane 307 is a ground plane that may be floating with respect to the split-ground of electrical interface 200. Copper isolation plane 307 is positioned

between high-voltage power supply 260 and the circuitry of transmitter 230 and 240 in order to provide electrical isolation. Electromagnetic signals emanating from high-voltage power supply 260, then, are blocked by isolation ground plane 307 before interfering with the signals of receiver 230 and transmitter 240. Each ground, the split grounds of electronic interface 200 and copper isolation plane 307, are coupled to ground external to multi-layer board 130.

[031] As such, high-voltage power supply 260 and high-speed receiver 230 and transmitter 240 are assembled on multi-layer board 130 and the internal construction of multi-layer board 130 provides shielding to isolate high-voltage power supply 260 from high-speed receiver 230 and transmitter 240. Multi-layer board 130 also utilizes “blind vias” for interconnects between layers.

[032] **Figure 4** shows an embodiment of electrical interface 200 that can be implemented on multi-level board 130. Electrical interface 200 includes a receiver portion 230 and a transmitter portion 240. Receiver portion 230 includes connector 210 and amplifier 212. In some embodiments, amplifier 212 can be a MC2048C-06-T amplifier available from Mindsped, Inc. In some embodiments, board trace 210 can provide connections for a bias voltage, power, ground, and a differential signal output. In some embodiments, the bias voltage can be large, e.g. about 70 V. Power can be supplied through connector 131 and can be, for example, about 3.3 V. The differential signal can be filtered in an integrating filter 214 before being input to amplifier 212. The output signals from amplifier 212 can be coupled to connector 131.

[033] Transmitter portion 240 includes board traces 220 and laser driver 222. Laser driver 222 can be, for example, a MAX3735 driver available from Maxim, Inc. Board traces 220 are capable of providing signal, power, and ground to TOSA 120.

[034] Electronic interface 200, in some embodiments, can be controlled by a microcontroller system 250. Microcontroller system 250 can include a microcontroller 254 that can be coupled to a memory 252 where data and program instructions can be stored. Microcontroller 254, for example, can be an MC3000 microcontroller available from Micrel, Inc. Memory 252 can, for example, be a DS18455B-50 memory chip available from Maxim, Inc. Microcontroller system 250 can receive signals from amplifier 212 of receiver portion 230 and from laser driver 222 of transmitter portion 240 in order to control and monitor aspects of electronic interface 200. Microcontroller system 250 can also be coupled with connector 131 so that data can be communicated out of electronic interface 200.

[035] High DC voltage can be generated in switching power supply 260. Switching power supply 260 includes switch 262, transformer 264, and rectifier circuit 266. Switching circuit 262 may, for example, be a MAX1605 switching circuit available from Maxim, Inc. Switching circuit 262 provides a low voltage, for example 3.3V, signal to transformer 264. The low voltage signal can be a square wave signal or sine signal with frequency of about 240 kHz. Transformer 264 steps up the voltage to the desired high-voltage level, for example about 70V. Rectifier circuit 266, then, rectifies the signal from transformer 264 and provides a DC voltage for use, for example, in ROSA 110 as a bias voltage. Some embodiments of electronic interface 200 may include further filtering and other signal shaping circuits. The voltage from rectifier 266, for example, may be utilized in sampler 268 to provide a monitor signal to microprocessor 250. Sampler 268, for example, can be a 1N168 chip, which can be obtained from BurrBrown, Inc.

[036] Switching power supply 260, in addition to providing higher DC voltages for aspects of transceiver 100, also is a large source of noise and interference for signals received at board traces 210 and, to a lesser extent, provide noise for transmission of

signals through board traces 220. Therefore, receiver portion 230 needs to be shielded from switching power supply 260. In conventional systems, high-voltage power supply 260 can simply be separated by a large enough distance from the remainder of electronic interface 200 that the interference is minimized. This solution, however, provides for a very large form factor for transceiver system 100. Instead, in accordance with the present invention, a split ground plane in multi-layer board 130 can be utilized to shield receiver 230 and transmitter 240 from high-voltage power supply 260.

[037] As is shown in **Figure 4**, the ground signals utilized in transmitter portion 240 and in high-voltage power supply 260 are split from the ground utilized in receiver portion 230. As shown in **Figure 4**, the two grounds are indicated by the separate ground symbols (∇ and \equiv). Further, to provide further shielding, receiver portion 230 and transmitter portion 240 is primarily formed on the bottom layer of multi-layer board 130 while switching power supply 260 are primarily formed on the top layer of multi-layer board 130.

[038] **Figure 5A** illustrates the metal traces for layer 301 (**Figure 3**) of multi-layered board 130 where electronic interface 200 as illustrated in **Figure 4** is implemented. Further, the metal traces of board traces 131, 220 and 210 are shown. Additionally, interconnections and vias are shown.

[039] **Figure 5B** illustrates the component lay-out on layer 301 according to some embodiments of the present invention. As is shown, transformer 264 is prominently placed on board 301. Additionally, switching circuit 262 is placed proximate to transformer 264. Rectifier 266, which in the embodiment of electronic interface 200 shown in **Figure 4** includes diode D1 and capacitor C12, is proximately arranged about transformer 264. Additionally, sampling circuit 268 is positioned on layer 301. Because

the signals for microcontroller 250 are of slower speed and are relatively unaffected by interference from high-voltage power supply 260, part of microcontroller 250 can also be positioned on layer 301. In the embodiment shown in **Figure 5B**, therefore, memory 252 is positioned on layer 301.

[040] **Figure 6** illustrates the arrangement of vias 600 on layer 302 of multi-layer board 130. Vias 600 provide interboard interconnects in order to affect the electronic circuitry of electronic interface 200. Vias 600 are “blind vias” in that, when multi-layer board 130 is assembled, electrical connections are made when the board is aligned, without specific alignment of the vias themselves.

[041] **Figure 7** illustrates the arrangement of vias 700 on layer 303. Additionally, layer 303 can provide a copper plane 701 to provide electrical isolation under high-voltage power supply 260.

[042] **Figure 8** illustrates electrical interconnects 801 on layer 304. Interconnects 801 can provide electrical connections between vias on layer 303 and layer 305.

[043] **Figure 9** illustrates vias 900 on layer 305. Further, layer 305 can also include further copper plane isolation 902 for further isolation of receiver 230 and transmitter 240.

[044] **Figure 10** illustrates the arrangement of components on layer 306. As is shown, laser driver 222 of transmitter 240 and amplifier 212 of receiver 230 are arranged on layer 306. Additionally, microcontroller 250 is also mounted on layer 306. Electrical connections between microcontroller 250 and memory 252, which is mounted on layer 301, are made through multi-layer board 130.

[045] **Figure 11** illustrates a cross section of multi-layer board 130. Layers 301, 302, 303, 304, 305, and 306 are stacked and interconnects are made through vias 1101 in and metallic traces in multi-layer board 130.

[046] Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims.